

# LARGE AREA POSITION/PROXIMITY

## CORRECTION DEVICE WITH ALARMS USING (D)GPS

### TECHNOLOGY

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#### FIELD OF THE INVENTION

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This invention relates to defining and detection of a 3-D boundary or volume using (D)GPS technology. In particular, it relates to an integrated instrument and method for inputting coordinates, processing these coordinates, and taking a corrective action with respect to the boundary. Full duplex Communication is featured for inputting coordinates, as well as reporting information such as location, speed, medical parameters, satellite health etc. The device has the capability to call or transmit important information such as location, speed, identity, and medical parameters etc to a station automatically or when polled. All necessary analog and digital circuitry, (D)GPS hardware, microprocessor, programming, communications hardware are fully integrated into the collar.

#### BACKGROUND OF THE INVENTION

This invention is referenced to Provisional application no.60/258246 filed December 26,2000.

*Sub 2*

The current practice and state of the art in the pet containment industry is to use radio waves to detect when a pet such as a dog has become too close to a boundary. In these systems, it is required that the pet owners bury a wire around the perimeter of the boundary and connect a modulated signal generator to the wire loop. The pet then wears a special collar that detects the electromagnetic field emitted from the wire loop and administers a correction signal to the

animal when it approaches the boundary. The wire is buried around the perimeter of the yard, and the active zone of the collar can be adjusted by increasing or decreasing the amplitude of the signal generator.

The collar usually contains a two axis pickup coil to detect the magnetic fields around the loop, and the necessary electronics to discriminate against noise, and then amplify and compare signals to produce a high voltage shock. Although these systems are not visible on the property, and they are less laborious to install than a standard post fence, there is still quite a lot of work involved in burying the wire loop. Furthermore, there is a maximum area which can be attained.

In the past, wireless systems have been developed to overcome these problems. US patent 5381129 issued to Radio Fence describes a system that incorporates transmitting antennas installed on the property and a collar worn by the dog to process the antenna transmissions and deliver a shock when the dog advances to a boundary. However, the complexity and expense of these systems makes them undesirable. Furthermore, the spacial resolution is limited for precise boundary discrimination. It is therefore the object of the present invention to provide a position proximity device based on the Global Positioning Satellite system or (D)GPS network.

Prior attempts to produce a GPS based containment system have had limited success, primarily because of their approach. For instance, US patent 6,271,757 issued to Invisible Fence INC. is a GPS containment system that is not self contained needing an external computer to perform all calculations and decision making. 757 are a continuation patent based on US patent 6,043,747 by the same company. In this embodiment, a separate portable programming transceiver is

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necessary to program the boundary of a selected confinement area as the transceiver is moved along such boundary. A separate collar to be worn by the dog, and a separate computer at a base station to process the data are necessary for the system. Up to three separate GPS systems are needed for operation, with a minimum of two.

US 6,271,757 teaches an invention whereby the user walks the perimeter with a separate transceiver, and the transceiver simply transmits the coordinates to a Windows based PC located at the house. The PC then stores the information and contains software to map out the boundary. It is also the function of this patent that in the running mode, the dog collar transmits the GPS coordinates to the PC, the PC performs all computations and decides if the dog has breached the safe zone. If so, then the PC issues a separate radio signal to the dog collar, which activates a correction signal. Hence, in this system, the collar only relays information and all processing is performed remotely. As one can see, it is necessary for this invention to need at least two GPS systems. A dog collar containing a GPS receiver and a radio link for the coordinates, a portable programming transceiver with a GPS system including a radio link for the coordinates, a PC, a communication device on the PC and additionally a satellite monitoring computer with a GPS system and modem. Furthermore, this invention is only operable in 2 dimensions and all equipment must function in conjunction with the external control station. To program the boundary, the transceiver requires the operator to press buttons to add points, and it must be told which areas are safe, and which are excluded. An added problem with this invention concerns multiple targets. In this embodiment, the control station must address all dogs, and the control station must compute, decide, and execute simultaneously to all dogs in an area through some addressable technique. Clearly this is an expensive and complicated solution.

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Other prior art includes US patent 6,868,100 issued to Marsh. This invention also requires a separate boundary definition transmitter to record data to a portable unit and discusses a fixed station for addressing the livestock. For livestock management, all processing is performed at the external processor and only simple area geometries are discussed.

### (SUMMARY OF THE INVENTION)

A GPS signal contains a pseudorandom code, ephemeris data and almanac data. The pseudorandom code is simply an I.D. code that identifies which satellite is transmitting information. Ephemeris data, which is constantly transmitted by each satellite, contains important information about the status of the satellite (healthy or unhealthy), current date and time. This part of the signal is essential for determining a position. The almanac data tells the GPS receiver where each GPS satellite should be at any time throughout the day. Each satellite transmits almanac data showing the orbital information for that satellite and for every other satellite in the system.

<http://www.navcen.uscg.mil/gps/geminfo/global.htm>

The present invention provides a totally integrated (D)GPS system with all signal processing, computation and communications on board in a single package. With this device, the need to transmit position signals is unnecessary leading to an economical and portable battery operated position/proximity correction device for use in pet containment. The uses of this device are numerous with applications in land, air and sea navigation, farming, construction, tracking stolen vehicles, keeping track of patients, children and even house arrestee's. Important Military

applications would include the warning and directing soldiers of front line boundaries, mine-field mapping and 3-D vectoring around MOA's for aircraft navigation to name a few.

*Sub A*

It is a more specific object of the present invention to provide a 3-D (D)GPS based boundary position proximity correction device with alarms that is totally integrated into a collar or clothing. The boundary can be mobile. The device has onboard an embedded microprocessor, memory, RF electronics, analog and digital circuits and means for two-way communication to a mobile or base station. Means to input two or three-dimensional coordinates is included along with software to operate the device. The alarms can be correction signals such as a shock, audible, voice or even a feedback control system for navigation. When the boundary is approached, means to contact a mobile or base station are included, to alert authorities and transfer important information such as the identity, location, speed and even physiological parameters of the subject. The base station can also poll the device and download new coordinates if desired. Each collar can also be defined as a mobile boundary. In this use, communication between collar subjects can define additional boundaries to avoid, or stay close to.

A typical embodiment of the present invention is shown in Figure 6A. In this configuration, the module is used to keep a pet inside a defined boundary. Note that there are many embodiments that this programmable device will apply. Just a few examples are listed in Figures 6A through 6F. In each example, the boundary volume is defined with safe zones, unsafe zones, soft zones dynamic zones, and hysteresis zones. The dynamic zones could represent moving aircraft on the ground or in the air. Similar systems such as TCAS operate off aircraft transponders and are disabled near the ground.

This invention is applicable in the air or on the ground. In these examples, two way communications collar to collar, or collar to base are established, and specific algorithms are incorporated to notify a station when a subject has crossed a boundary, or to apply a corrective or warning signal. Subjects can be included in a boundary, excluded in a boundary, the union of multiple boundaries can be arranged.

For animal control, after the module has been programmed with the proper coordinates, the module will sound an audible alarm when the animal is within a distance  $x$  of the boundary, and a correction signal will be applied when the animal is within  $x-\delta$  of the boundary. Currently, values of  $x$  are 5 to 10 meters, and  $x-\delta$  could be as close as 2 meters using current differential mode of the GPS module. Because of the noise in the system, and using proper design methodology, hysteresis at a boundary is implemented. With improvements in the GPS technology, the accuracy of the invention can be improved.

In one embodiment, the collar can contain a module shown in Figure 3 manufactured by  $\mu$ -BLOX in Zurich Switzerland. The GPS-MS1E-AT is a fully self-contained receiver module based on the SiRFstar chip set with a Hitachi risk microprocessor. For development, an evaluation kit such as the u-blox can be purchased GPS-MS1E-SCK with a Hitachi C compiler, which was included in the customization kit. This system contains all the command sets necessary to modify the  $\mu$ -BLOX programming codes for a particular task. The  $\mu$ -BLOX MS1E-AT also has the capability to transmit the module coordinates through its AT command set. Not limiting this invention to a particular method of transmitting, the AT system in

communication with, but not limited to, a GSM type modem as one such method to real time track the position of an animal, person, or thing with the ability to immediately locate the subject. In this mode, the subject's location can be found in the specified boundary, when it crosses a boundary, or when it is polled to report a location. The subject can also request poll in particular uses such as illustrated in 6E. Here, a patient can activate the collar for requested assistance. For hunting dogs, it may not be necessary to use the one or both alarms, and the position and velocity of the animal could be polled any time. By using velocity and acceleration vectors, position estimates can be calculated.

DO NOT  
WALK  
WITH  
A  
COLLAR  
ON

The antenna is currently an active microstrip antenna. However, it could be a passive antenna or an antenna loop embedded in the collar of the animal or structure.

There are many ways to program the GPS module. For instance, in one method, a laptop or Palm Pilot could plug into the collar port 7. In this mode the laptop could download the coordinates from the boundary into the collar where the coordinates would be stored in its memory. In another method, the coordinates could be hand entered off a map and loaded into the collar by port 7. In another embodiment, a mapping extracted from a web-based application such as the GIS system could be used to download three-dimensional coordinates, and then the collar would specify the volume of interest and store the data.

In the most favorable method of training the collar, the microprocessor in the collar would handle all the calculations. In this mode, the collar would be placed on the pet, and the pet would be walked around the boundary. During this walk, the collar would read the location coordinates

and stores them in the proper memory slot in the onboard computer. The embedded software then stores and maps the boundary during this "training phase". In the operational phase, the embedded processor reads the 3-D coordinates, compares these real time coordinates to the boundary or surface, and sounds a plurality of alarms when the subject approaches the boundary.

The embedded processor can also analyze the site to make sure that the reception is satisfactory for use. In the event that a weak signal was detected, steps could be undertaken to solve the problem. In one design, "SignalView" program could simply incorporate the use of an output pin on the GPS-MS1E. This pin detects faulty satellite operation and can idle the system until good satellite data is observed. The MS1E like many systems has a "trickle power" feature. In the event that the animal is asleep, and no movement is detected, the GPS module would also go to sleep to conserve power. Upon detecting animal movement, the processor would become more active.

For enhanced operation, this system is DGPS ready. In this example, RF communications could transmit the coordinates of a base station in RPCM SC-104 format to the port on the collar.

In the operational phase, a coordinate is read from the satellites. Next, the software compares the coordinate to the list stored during the training phase, and finds the closest queue point. Then, through 3-D triangulation the  $\mu$ -BLOX GPS-MS1E decides if the subject is within bounds. In the event that the subject ventures out of bounds, the system will have the ability to report to a base station the coordinates of the module and take evasive action.

The base station shown in Figure 5 is used for two-way communication between the collar and a base camp. This station could even be a cell phone with the proper programming. The station could also be used as stationary differential GPS correction device since the location of the station will be precisely known. In this mode, any error in the received GPS signals would be passed along to the collar if it were operated in the differential mode. However, the Nationwide Differential GPS Service will soon be available allowing differential mode to be incorporated in the operation of the collar without a plurality of receivers.

If the subject is capable, inverse polling could also occur as requested from the collar. In this event, a lost person could transmit their coordinates to the base station.

In the following pages, years of research and design will be described concerning the prototype GPS proximity detector with alarm.

#### BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1 shows the collar system. The system includes a leather or textile animal collar 1, a GPS module with receiving electronics and memory 2, a GPS antenna 3, an electronic module 4 with means to sound an audible alarm 5 and means of a correction signal such as a shock or other corrective action. Two conducting prongs 6 that are powered by a watch battery and the necessary high voltage circuitry deliver the shock. The audible alarm could be a piezoelectric crystal. A computer port 7 allows communication with the GPS module for downloading coordinates or uploading data from the GPS-MS1E -AT-DL datalogger. A wire 8 is necessary to

electrically connect the electronic module with the GPS module. This wire contains power and a signal to switch the alarms on and off. A separate communications antenna is shown in 9 for two-way data link. A single antenna could serve the purpose of both the GPS and communications network.

Figure 2 shows a typical boundary monitored by this device. The boundary is allowed to be three dimensions. In this illustration, the main boundary 9 could connect a number of sub-boundaries 10 by a corridor 11. Each coordinate is defined in 3 dimensions. In this flexible device, boundaries within a boundary can be easily defined. The keep out zones could be a minefield. Around the total area is a soft zone. This area acts as a "spacial hysteresis ". After the dog crosses this hysteresis zone, different correction algorithms take place.

Figure 3 shows an external module programmer. The actual (D)GPS chip is shown in figure 4. It is a development kit purchased from u-blox and is sold with all software necessary to develop this project. It contains all necessary electronics analog and digital to build a "large area proximity detector with alarms". After programming the chip in this box, it is removed and placed in the portable application device. The programmer is housed in a box 12, which the GPS module 13 is inserted. The programmer contains the necessary electronics 14 with means of communication through an RS232 connection 15. By utilizing the IO pins inside the programmer, attaching the antenna and communicating through the ports, this invention can be realized.

Figure 4 shows the GPS-MS1E-AT-DL module. By simply adding an antenna, a battery, and downloading the code to the module the task of boundary identification can automatically begin. It is slightly larger than a postage stamp and in particular is 30.2mm x 29.5mm x 7.55mm and plops into a standard 84 pin PLCC. As it is the purpose to teach one skilled in the art to build this device, the data sheets are included in Appendix A.

Figure 4c shows a (D)GPS module complete with receiver 18, transmitter 19, computer with memory 20, and serial interface 21 such as RS232 or USB. The interface could be linked by any standard method such as cable, infrared, wireless serial or parallel.

Figure 5 shows an optional base station 16 complete with an antenna 17 for two way communication with the collar and another antenna 18 which could be used for a differential DGPS station when accuracy is of concern. A LCD 19 is necessary in order to read and map the coordinates when the collar is polled, and for any diagnostics needed on the base-station. The base station could be a stand-alone unit built by the collar manufacturer, or it could be a wireless phone with location capabilities and of the new 3-G design. The capability to reprogram individual collars in the field and manage a heard is built into the station. However, each collar can communicate with other collars eliminating the need for exterior management.

Figure 6 shows the system installed on a dog 6A, an automobile 6B, a bulldozer 6C, an airplane 6D, and a person 6E. In these illustrations, the GPS module 2 and antenna 3 are combined to form an integrated system 20.

Figure 7 shows the necessary hardware modifications to make the GPS chip battery operated and field ready.

#### DETAILED DESCRIPTION OF THE INVENTION

The present invention will now be described more fully hereinafter with reference to the accompanying drawings, in which the preferred embodiments of the invention are shown. This invention may be embodied in many different forms and should not be construed as limited to the embodiments set forth herein; rather, these embodiments are provided so that this disclosure will be thorough and complete, and fully convey the scope of the invention to those skilled in the art.

A fully integrated (D)GPS electronic boundary proximity system shown in figure 1 is provided for animals, objects, for tracking movement, reporting coordinates, and taking evasive action relative to a selected containment volume. Attached to each animal 100 is a fully integrated (D)GPS collar 1, and surrounding the pet is a volume 101 referred to as the "object space". The object space 101 can be uniquely defined by a vector V 102 representing the object space as a point. Satellites 103 transmit and are received by the collar 1 and possibly a base or mobile station 16. In this invention, the collar 1 processes the information received from the satellites 103 to detect a boundary space 105 defined by a multiple of areas such as 9, 10, corridor 11, exclusion zones 12, soft zones 13, and exterior zones 14. All areas can be represented by lines

for two-dimensional representation, or surfaces for volumetric representations as indicated in figure 1. Two-way communications antennas 104 are included on the collars 1 and the base station 16.

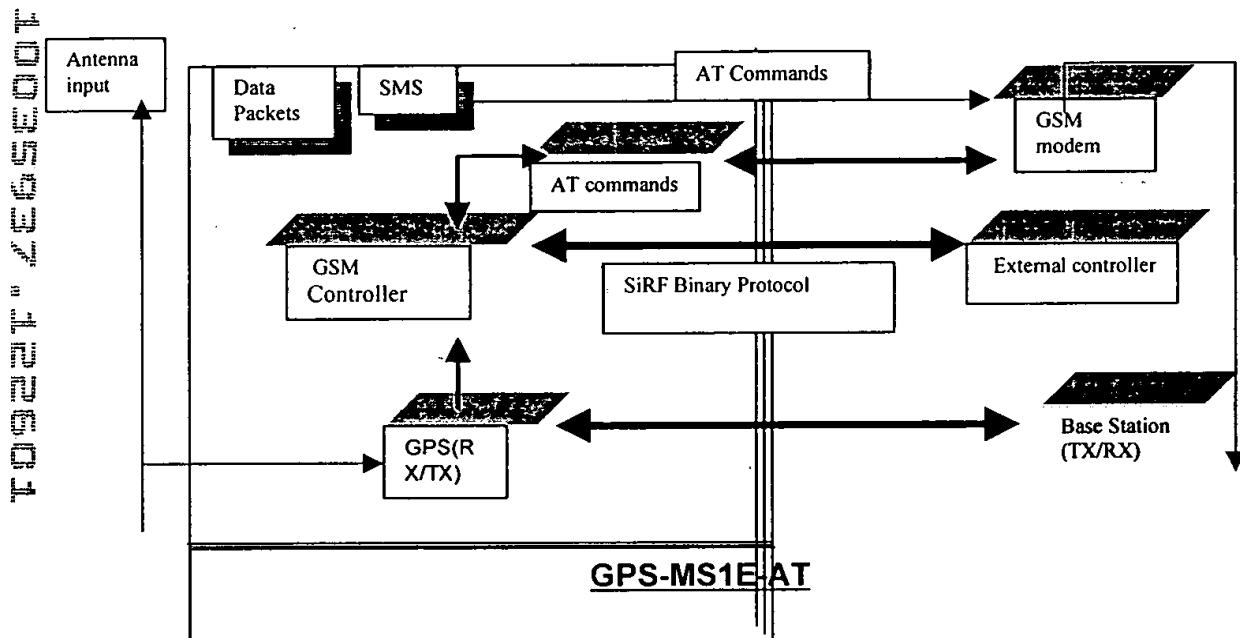
The containment volume 105 is defined using the collar 1 illustrated in figure 2. The collar receives (D)GPS signals from the satellites 103 and processes the raw data into x,y,z position coordinates. The collar system consists of means of attachment such as a leather band 1, an electronic module 2, a GPS antenna 3 a communication antenna 9, a digital port 7 wiring 8, a correction stimulating device 4, high voltage prongs 6 and an audible signal generator 5. Both 9 and 3 could be integrated into a single antenna for consolidation purposes. The collar is attached to an object such as an aircraft, or a pet as indicated in Figure 6A-E

The collar can be based on many manufactures of GPS electronic parts, Figure 4 shows one such system; a GPS-MS1E-AT manufactured by u-blox. The module 106 contains a microprocessor 107 memory 108 RF section 109 an antenna 3, eight IO ports 110, and two GPIO ports 111. In the preferred embodiment, all electronics are integrated into the collar as shown in Figure 5. In this example, the (D)GPS 106, communications 107, correction 4, and supporting electronics 108 modules have been integrated into a single package 2.

The communications module 107 can be based on any wireless method of communication. Several such limited examples such as CDMA, TDMA, FDMA are well known to one skilled in the art. In one embodiment, GSM techniques could be incorporated using off the shelf parts. For integration with the u-blox system, one embodiment would require a GPS receiver (GPS-MS1E-

AT), a GSM modem supporting AT interface (GSM 07.05,07.07) and a controller. The controller reads positions from the GPS receiver and controls the on board digital modem. A schematic of the communication system is shown in figure 7.

u-Blox offers an integrated control system for GSM modems with the AT command interface for GPS receivers. This system is designed for autonomous operation. An external controller is not required, however, it can be used for enhanced functionality.



An external controller may communicate with the GPS receiver via a serial port with the SiRF binary protocol. The GSM modem is controlled through the GPS receiver. The antenna input can be connected to the GPS-MS1E to receive signals.

In this example, the advantages of integrating with GSM Control Software are:

- Fully compatible to standard u-blox GPS receivers
- Configuration through the serial interface
- Designed for autonomous operation
- Minimal external circuitry and no external controller required

An external controller may communicate with the GPS receiver via a serial port with the SiRF binary protocol. The GSM modem is connected to the other serial port and is controlled through the GPS receiver.

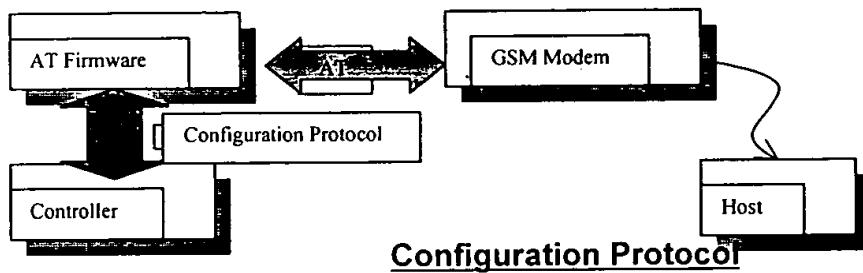
The GSM controller is event driven. For each event an action and the data transmitted can be defined. Events (triggers) may be the output of the GPS engine (position, time) or an external signal. If the conditions for a trigger are met, the assigned action will be performed. This assignment is set during the configuration of the GSM controller. A trigger is assigned to each event, for example,

| I.D. | Event/Trigger | Condition  | Parameters   | Range     |
|------|---------------|--|--------------|-----------|
| 04   | Movement      | The distance to the last position is above the adjusted value. | Distance [m] | 0-320000m |

Action can be assigned to the different events. Any action consists of one out of four possible phone number and the data, which will be sent. For example,

| I.D. | Action   | Description                      | Remark         |
|------|----------|----------------------------------|----------------|
| 01   | Data SMS | Send a Short Message in PDU Mode | 8 bit data SMS |

When the base station (TX) sends a signal and requests the coordinates of the GPS-MS1E-AT(RX), events are triggered, the GSM controller will be triggered based on the events. For each event an action and the data transmitted can be defined. Events may be the output of the GPS engine (position, time) or an external signal. If the conditions for a trigger are met, the assigned action will be performed. The GSM controller can control the sending of the AT commands through the configuration protocol. Only SiRF binary protocol can be used to control the AT command Firmware. The AT commands will then be sent from the GSM controller to initiate the modem. The control and communication with the AT command firmware is performed using the serial interface.



To transmit the coordinates back to the base station, action can be triggered by the use of the AT Firmware. GPS-MS1E-AT communicates with a GSM modem via the AT-standard (GSM 07.05, 07.07). Firstly, the action *RX* turns on the GPS modem, that means sending the action *RX* to the modem awakes the modem and enables it to receive calls or SMS. The action *Data Call* then opens a data connection to a host. There are two modes used for data calls. In data mode you can send the same requests to the module as in SMS, a request also has to be sent at least every 30s to keep the connection alive. In online mode you will have to answer "sense" messages to keep the connection up. If a data connection is opened, the AT-Firmware enters data mode. Data will eventually be transferred back to the requested host by the configuration protocols, which the AT-Firmware uses to communicate with hosts.

### **Connection to the GSM Modem**

The GPS receiver does only have to be connected to the serial port of the GSM modem. Some GSM modems support an external pin to switch the modem on. For modem with support of this function, we recommend to connect this pin. This allows the controller to restart the modem in case of problems. For example,

| MS1E pin name | Signal Name | Modem line Siemens M20 | Modem line Falcorn A2D | Modem line Wavecorn WMOD2D |
|---------------|-------------|------------------------|------------------------|----------------------------|
| TX0           | Modem RX    | USCRX                  | DATA_RX2               | RX                         |

Before a modem can be used with the AT option, the modem has to be configured. A PC with a serial port and a terminal program is needed to do this. For the modem has to be connected to a serial port of the PC

and the terminal program has to be opened on that serial port. Normally after applying power, a switch on signal has to be generated to turn on the modem. Sending AT<CR> should cause the modem to answer with OK<CR><LF>. If strange characters are returned the baud rate of the serial port is wrong. If nothing is returned, the serial connection may be broken or the modem is not on. There are external wires that must be connected to the modem. If we want to use a mobile phone with AT interface, you probably do not have access to the on/off reset signal. If we do not connect the on/off and reset lines(not recommended), we have to activate no power up mode in the configuration.

Hayes set a standard for modem commands with its Smartmodem 300. Most modem manufacturers adopted this command set in order to call themselves "Hayes compatible." The command set used by the Smartmodem 300, as well as most modems today (with a few advanced commands), is known as the AT command set. AT stands for attention, and precedes all (with the exception of A) commands directed to the modem. For example, when dialing, it is necessary for either the software or the user to issue an ATDT or ATDP command followed by the number and enters. AT tells the modem that it is about to receive a command. DT tells it to dial by tone, while DP tells it to pulse dial.

Finally, the modem dials the number given to it after the command. Different modems do have slightly different command sets, but generally most modems follow the standard set by Hayes.

Examples:

%Cn -- Enable/Disable Data Compression  
%En -- Auto-Retrain control  
&Cn -- DCD Control  
&Dn -- DTR Option  
&Fn -- Recall Factory Profile

Figure 6 shows the base/mobile station 16. This station contains a readout screen 19, a communications antenna 17 and all the necessary hardware to communicate with the collar 1. In one embodiment, the base station can be used as a differential station whereby it would include a GPS module 18. Here using standard differential methods, corrections could be passed to collar 1 through antenna 17. The base station could also be used to download new boundary coordinates to a subject 20 wearing the collar 1. This would be especially useful in military operations to adjust front line boarders, or send coordinates of dangerous areas such as mine fields.

In one embodiment, the correction module 4 is in communication with both the GPS chip 106 and communications hardware 107. For pet containment, and livestock control, the correction hardware consists of an audible device 5 and/or a behavior modification device such as a high

voltage stimulus 6. Figure 8 shows a typical correction device where LM 317 adjusts the intensity of the shock 112, 113 is a pulsar based on the LM 555 timer necessary to excite transformer 115, and 114 is a MOSFET switch for isolation. When the MS1E detects that a subject is dangerously close to a boundary, it will activate an IO line 110 internal in 106 and after signal conditioning, will transmit through 8 a correction signal. This signal could be audible as in 5, or a shock such as 6. In the event that the correction hardware was to take control of a situation, the feedback control data link 116 would upload or transmit any signals necessary external to the module 2.

In the training phase, the collar 1 has the capability to define a volume 1b, while in the implementation phase, the collar 1a can communicate 300 to a base station 16 or to another collar 1. This information may consist of an exchange in coordinates, change in coordinates, rates of change of coordinates, or information such as identity and physiological parameters of the object. With this system, each object 20 can be defined as a volume  $\Delta V$  101 and have its centroid coordinates 102 passed from collar 1 to collar 1 or to a station such as 16. The coordinates may be transmitted continuously, non-continuously, or when polled by another collar 1 or the base station 16.

The operating system consists of training phase, and a running phase, means of communication and computation all integrated in into a portable package. Although a mobile or base station is not required for basic operation, it can be used in this embodiment.

In the preferred embodiment, the collar 1 is worn by a pet and accepts GPS signals through antenna 3 and processes them through the RF section 33. These signals are digitized to produce

location coordinates, which are stored in memory 32. A computer program also stored in memory 32 has the ability to operate on these coordinates as a function of time and space. A flow chart for this program is seen in .....

All analog and digital support electronics are also placed inside 2 as indicated in figure 3. Item 60 has been expanded in Figure 5 , which illustrates a GPS1 connected to power supplies and regulators. This section also contains analog and digital electronics batteries, necessary to support the communications section of 2, power any antennas as well known by one skilled in the electronics area.

Regular GPS receivers, when first switched on, can take several minutes to find four satellites, which isn't acceptable for location-based services. (A cell phone's battery would be drained too quickly if it kept the GPS receiver on all the time.) Instead, most will use a solution called Assisted GPS, which also keeps an active GPS receiver at every base station. This broadcasts the precise time eliminating the need for a fourth satellite-and tells the phone where to look for the other three satellites.

Assisted GPS is particularly useful in Code Division Multiple Access (CDMA) networks, because all of their base stations already include GPS receivers. (CDMA systems need to know the precise time for synchronization purposes, and the GPS time signal provides the accuracy of an atomic clock at a much lower cost.) It also has two other benefits: the base stations act as a backup when satellites aren't visible, and it can be more accurate.

Most satellite systems require a clear line of sight between the satellite and the receiver. The GPS signals are slightly more resilient - they can pass through many windows and some walls - but they still won't work deep inside a building or underground. Assisted GPS can fall back to base station triangulation in these situations, providing at least some information whenever a user is able to make a call.

Qualcomm Incorporated, pioneer and world leader of Code Division Multiple Access (CDMA) digital wireless technology, announced the RFR3300, an RF-to-IF (radio frequency to intermediate frequency) front-end receiver designed for cellular, personal communications service (PCS) and Global Positioning System (GPS) signal processing in May 2000. The RFR3300 device is the first in the CDMA industry to integrate GPS capability with a CDMA front-end receiver.

The RFR3300 device is silicon germanium (SiGe) BiMOS radio frequency integrated circuit (RFIC) that provides high linearity with very low power consumption. The advanced integration of a GPS receiver into a CDMA/AMPS receiver eliminates the need to add an extra stand-alone GPS RF receiver. Together with Qualcomm's MSM3300 Mobile Station Modem (MSM) chipset and IFR3300 baseband receiver, the RFR3300 device offers the cost-effective and high-performance solution for dual-band (PCS CDMA and AMPS) or tri-mode (cellular CDMA, AMPS, and PCS CDMA) phones with Qualcomm's gpsOne position location technology. The gpsOne solution offers robust data availability under challenging conditions, such as in concrete-and-steel high-rises, convention centers, shopping malls or urban canyons.

Qualcomm's RFR3300 device integrates dual-band low noise amplifiers (LNAs) and mixers for downconverting from RF to CDMA and FM IF, and contains a dedicated LNA and mixer designed for downconverting global positioning system (GPS) signals from RF to IF. The RFR3300 receiver operates in the 832 MHz-894 MHz cellular band, 1840 MHz-1990 MHz PCS band and 1575 MHz GPS band. The RFR3300 device meets cascaded Noise Figure (NF) and Third-Order Input Intercept Point (IIP3) requirements of IS-98 and JSTD-018 for sensitivity, and two-tone intermodulation. The RFR3300 solution was also designed to meet the sensitivity requirements of gpsOne.

The cellular LNA in the RFR3300 device offers gain control capability for improving dynamic range and performance in the presence of high levels of interference. Reducing the gain in the LNA also improves power consumption. Band selection and gain modes are controlled directly from the MSM3300 chip. The RFR3300 device is designed for use with voltage ranges from 2.7 V to 3.15 V, and is available in a 5 millimeter by 5 millimeter 32-pin BCC++ plastic package.

The MSM3300 chipset is comprised of the MSM3300 CDMA modem, RFT3100™ analog-baseband-to-RF upconverter, IFR3300™ IF-to-baseband downconverter, RFR3300™ RF-to-IF downconverter — the first front-end receiver in the industry to incorporate GPS capabilities in a CDMA chipset — PA3300™ power amplifier, PM1000™ power management device and the SURF3300™ development platform. QCT's gpsOne technology is integrated on the MSM3300 chip, which provides all of the position location capabilities without the need for additional chips, reducing board space and potential size of the handsets. QCT's gpsOne solution, featuring SnapTrack™ technology, offers robust data availability under the most challenging conditions, whether in concrete-and-steel high-rises, convention centers, shopping malls or urban canyons. Using a hybrid approach that utilizes signals from both the GPS satellite constellation and from CDMA cell sites, the gpsOne solution enhances location services availability, accelerates the location determination process and provides better accuracy for callers, whether during emergency situations or while using GPS-enabled commercial applications. The gpsOne solution deployed by KDDI is supported by SnapTrack's SnapSmart™ location server software, which provides the core position calculation function for KDDI's ezenavigation service.

<http://www.cdmatech.com/solutions/pdf/msm3300generation.pdf>

<http://www.cdmatech.com/solutions/pdf/positionlocation.pdf>

There are many technologies available for the communication as well as the GPS location electronics. For instance, The Qualcomm MSM3300 chip set has communications and location capability all in a single chip set. This system is based on (WA)GPS or "hybrid positioning" incorporating both cell phones and GPS. In another embodiment, "Bluetooth" could be used for communication for short range applications, less than 100m. The protocol for the communications system is also standard and could rely on GSM, TDMA, CDMA, FDMA or the like.

## References to the Research:

<http://www.u-blox.com>

[http://www.unavco.ucar.edu/science\\_tech](http://www.unavco.ucar.edu/science_tech)

<http://www.cdmatech.com/>  
[http://www.colorado.edu/geography/gcraft/notes/gps/gps\\_f.html](http://www.colorado.edu/geography/gcraft/notes/gps/gps_f.html)  
<http://www.arcx.com/sites/CDMAvsTDMA.htm>  
<http://joe.mehaffey.com/>

A limiting example of a program is now included.

The training phase of the software involves data collection, angle calculation and finally, storage of "essential" boundary points. To learn the boundary of an area, the user will walk around that boundary with the device. As the user walks around the desired boundary, the module records the current position. The training algorithm takes these points and, using simple geometrical equations, decides which of them constitutes a turning point, or sharp angle, in the boundary path. These angle points (or "essential" points) are then stored in an array that can be used to effectively, reconstruct the boundary path. This is accomplished by connecting each set of adjacent points through standard linear or polynomial methods. Boundaries within a boundary and 3-D systems are possible.

Upon completing the boundary by returning to the home position (the first stored point in the boundary array) the device automatically switches to the running phase. In this phase the device recalculates its current position. Using this position, it calculates the distance from each "wall" section of the boundary. Using the shortest distance found, it determines whether it is within a warning or error distance from the boundary. Based on this result it returns the appropriate output through the general I/O pins of the module.

## Software

The embedded software consists of three phases, a training phase in figure 12, an implementation phase figure 13, and a communication phase. Referring now to figures 1, 2, 6, in a preferred embodiment, the collar 1 is all that is needed to define a boundary or volume. This collar 1 is simply walked around the boundary 105 in a manner such that the coordinates are received from satellites 103, stored in the onboard computer in 106. In this example, the coordinates are read from the satellite and stored in the collar1 each second. It initiate the training phase, the user begins at a "home point" which is arbitrary and the training phase is initiated. This initiation could start by activating an internal switch in the collar 1, or by activating a soft switch using the port 7 on the collar. For example, the 3 coherent light pulses shined into the port 7 could act as a software switch to begin the training mode, and 3 long pulses and 3 short pulses could be used to activate a diagnostics mode. Using the window soft switch will allow designs more robust to the outside environment.

Figure 10 is a limiting example of the flow programmed into the collar1. In this example, the collar 1 is initiated into the training phase using the soft switch 7, 7b. At this point, the home coordinates are recorded and the collar begins collecting x,y,z coordinates and comparing them to previous coordinates. If the coordinates have not changed, the program ignores, but continues to receive coordinates. Here, each coordinate is compared to a multiple of coordinates stored in the Que. If the angle between the new coordinate and the set of points in the queue 204 is greater than some previously defined angle such as 150 degrees, the coordinate is stored and the collar continues to process a new point. In the event that the coordinate is found to be close to the home coordinate, the collar automatically stops the process and identifies the boundary as boundary 1.

If more boundaries are to be defined, the user activates the soft switch 7 using 7b, the counter is incremented and the new boundary is defined in the same method as the primary boundary.

For complicated boundary examples such as the union of 9, 10, 11, 12 as in figure 1, the user could begin by defining 9, first, then defining 10, 11, and then the internal boundaries 12. Each

area is defined as a separate region. The program would then assume that all external areas such as 9, 11, and 10 were secure zones, while all interior areas such as 12 were hazard zones.

Optionally, each area could be defined independently using the programming wand 7b to identify areas 9, 10, 11, and 12 as a hazard zone or a secure zone, whereby each type of zone would have independent codes.

Three-dimensional volumes as illustrated in figure 11 are programmed in much the same way. In one embodiment, an area 117 is programmed into the collar1, then again over another area 118 at a different altitude or z component. The software would then assign a secure area to the volume defined between the two areas. Figure 11 is in illustration of a three dimensional volume defined by this method. Parametric equations could also be incorporated to define surfaces. Conversely, the secure area could be outside of this defined area as opposed to the interior of it. Here, aircraft would be alerted that they were approaching a hazard space, and the correction hardware would warn the pilots or automatically take control by the feedback system 116. 3-D volumes would also have the ability to form the union of two spaces, allow corridors between spaces, and allow the definition of interior volumes within a volume. For terrestrial 3-D mapping, the collar 1 could simply be walked around an area such as 105 in figure 1, and then walked around upstairs 119 in the house as shown in figure 1. Here, the secure zone could be defined as certain areas upstairs 119, and the defined area 105. Anything not defined within a volume could default to either a secure or a hazard zone.

In another embodiment, an aircraft could fly a pattern at a first altitude, and again fly an altitude at a second altitude, and the collar 1 would define the 3-D volume between these two patterns as a secure or hazard zone. Then, other volumes could be defined interior or exterior to the primary volume, corridors attached, and a space for safe flying is thus defined.

In still another embodiment of the present invention, the coordinates could be downloaded in the collar 1 using the port 7. In this example, coordinates could be keyed into a device such as a PDA, laptop, or base/mobile station shown in figure 6, and through the communication software

downloaded by radio through antenna 17. In this manner, the space 105 is dynamic and fully programmable and addressable to each collar1.

Figure 6 illustrates the base/mobile station. This device 16 contains a microprocessor, a display, means of communication 17, and a GPS module 18. In one example, the base/mobile station could be used for a differential station where the coordinates are precisely known. By reading its position from satellites 103, any error correction can be passed to collar 1 for enhanced accuracy.

The display 19 could simply be a LCD the shows the parameters such as location, speed and diagnostics, or it could display the 3-D airspace and the proximity of an object to this display. Using the display, a collar programmer can see the defined space, and check for errors before downloading the boundary coordinates to collar 1.

#### Implementation phase:

When the collar has detected that the training phase has been completed, it switches to the run mode. In this mode, when the subject 20 surrounded by an object volume 101 approaches the boundary 105, a series of corrective actions take place. For instance, when the object 20 is 2 meters from the boundary 105 I/O a line in 110 goes high and an audible signal 5 is produced. When the object is 1 meter from the boundary, a second I/O line goes high, and a more serious correction signal such as a shock 6 takes place. Simultaneously, the communications software initiates a call from 30 and through port 9 sends the location data to base station 16.

Predictions of position can also be calculated by collar 1 using the velocity 102 and acceleration vectors. Here, if the subject is fast approaching the boundary 105, the digitally controlled correction signal amplitude and rate can be increased.

The present invention has the capability to define an object space 101 around each subject such as 20. In this example, each collar 1 is in continuous communication with a plurality of collars and the base station. In a limiting example, the communication data contains parameters such as location, speed, identity, and physical parameters of the subjects 20. When two subjects are found to be close to one another, the correction software warns each subject, and possibly the base station 16.

Each boundary 105 has a hysteresis zone adjacent to the boundary 105 or space 101. The purpose of a hysteresis zone is much like any feedback control system. This spacial zone is used to dampen the action of correction based on upgoing and downscale going of the measured variable such as location. In effect, it will keep any oscillation of the correction signals produced by 20 as is well known by control engineers.

If for example, the object breaches the secure zone, the embedded software in collar 1 will call the base/mobile station and alert the authorities, and after several attempts of corrective action will cease. In this manner, an escaped or lost pet such as 20 can continue to try and find home without penalty.

With the means and methods set forth herein of this invention, the following limited example of collar 1 programming is discussed.

QUEUE

The queue holds all the critical points, which will be used during the implementation phase. The training phase only determines the critical coordinates and stores these coordinates in the queue.

The X, Y, Z coordinate of each critical point is stored within one node on the queue. The first training lap uses these three points:

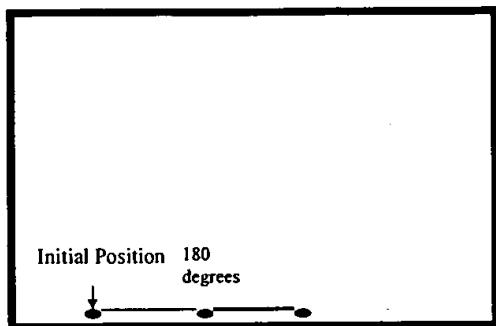
1. Last coordinate stored in queue,
2. Previous coordinate,
3. Current coordinate.

In essence, from the last stored coordinate the invention waits for 2 more acquisitions before starting to determine the sharp angle. This equation is a distance formula  $\text{Dist}^2 = X^2 + Y^2$  and the inverse cosine function. The second lap around the boundary secures parameter shapeliness using time sampling.

A simple height or Z dependence is also possible. Here, the height at the home position is one height stored. Then in the running phase, it simply checks if the current height is within the correction or warning distance from the ceiling or floor heights. This algorithm that could be used inside a structure such as a home. If the animal is allowed to be on the first floor, then the height could be used to keep the animal from venturing to the second floor. Also, using the corridor algorithm, the animal could be allowed to transverse up the stairs to a particular room, but be excluded from others. Conversely, it could be allowed to visit a neighbor, but only through a certain "path".

#### **Program Specifics:**

**TRAINING, First Lap:**  
Finding Sharp Parameter Coordinates



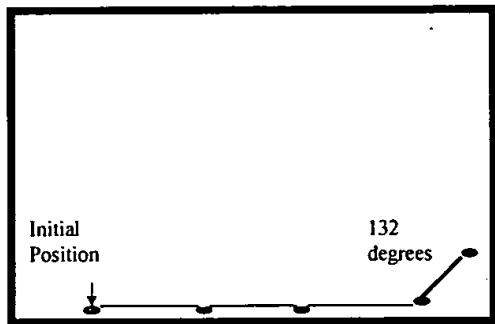
Time:  
10 seconds  
&  
3 coordinates

Thresh Hold < 151 degrees

Once a coordinate is acquired, the angle between that coordinate and the last acquired coordinate is calculated and if it is less than our threshold angle (151 degrees) that coordinate is stored in the queue.

**TRAINING, First Lap:**

Finding Sharp Parameter Coordinates



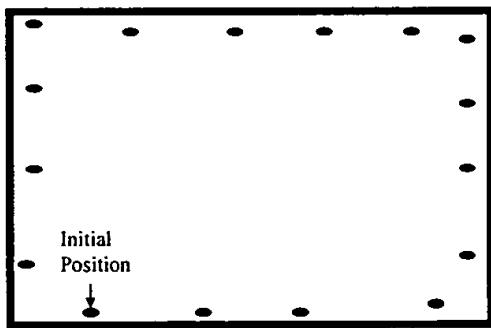
Time:  
30 seconds  
&  
5 coordinates

Thresh Hold < 151 degrees

Eventually, you will end up with all 4 corners of the specified area or boundary.

HOMEWORK  
EXERCISES

**TRAINING, First Lap:**  
Finding Sharp Parameter Coordinates



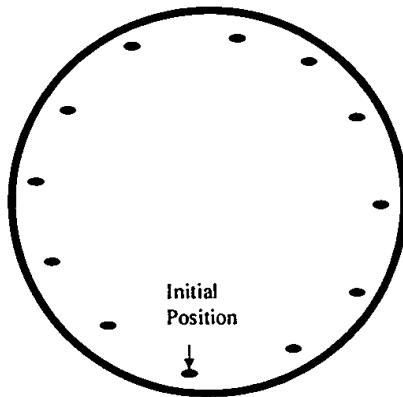
Time:  
1.8 minutes  
&  
16  
coordinates

Thresh Hold < 151 degrees

TO DO LIST

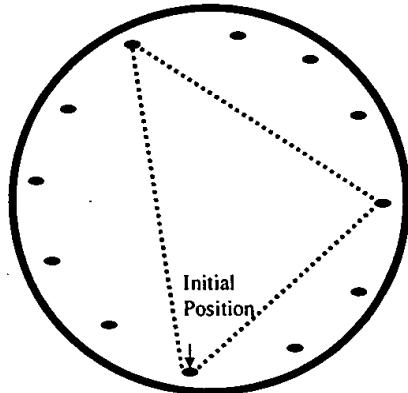
Of course, the possibility exists that our area perimeter is not a rectangle. For instance, if our perimeter is a circle, we would end up with a few coordinates but not enough coordinates to get the correct shape of the boundary.

Problems with critical coordinate algorithm



We could end up with a triangular perimeter instead of a circular perimeter like we needed.

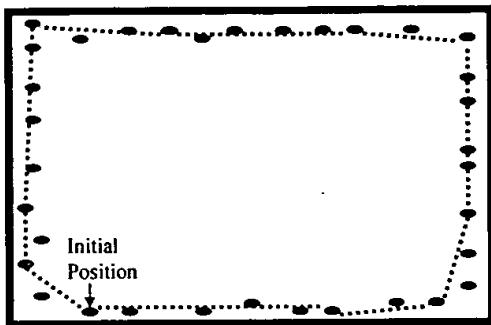
### Problems with critical coordinate algorithm



In order to avoid this problem, the invention includes a second lap in the training phase that utilizes a time sample. During the first lap of the training phase, time is kept so that we know how long it takes to make one lap around the perimeter. After breaking this time into intervals, we can know where to take additional samples. For example, with a rectangular area:

**TRAINING, Second Lap:**

Time Sample Coordinates



Time:

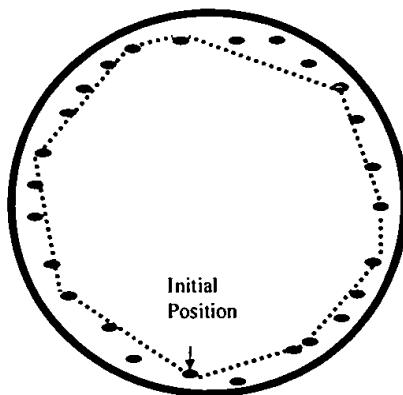
1.8 minutes  
&  
16  
coordinates

Thresh Hold &lt; 151 degrees

D  
O  
W  
N  
M  
A  
N  
U  
L  
A  
R

Now, if we apply this same concept to the circular area, we will have a boundary that looks like this:

Problems with critical coordinate algorithm  
FIXED

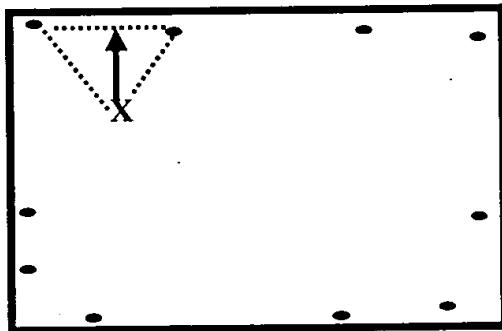


The implementation phase follows the training phase and includes the means to calculate the actual distance from the "wall" or boundary.

Once the boundary is stored in the collar 1, the device automatically jumps to the run phase where coordinates from satellites 103 are used to detect the subject 20's position. For example,

## IMPLEMENTATION:

## Determine Distance Away From Wall

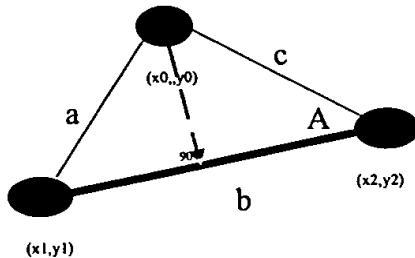


In this phase, an audible signal 5 will sound if the user is within a specified warning distance from the boundary. A shock correction 6 will be activated if and when the user reaches the boundary. If the warning distance and error distance is not reached, a green “in-boundary” LED will stay on.

## Calculations

In the following calculations, triangulation is used to determine the animal's distance to the boundary. If the subject is represented by the coordinates  $(x_0, y_0)$  in the basic geometric formula

Basic Geometric Formula



Sine Function:

$$\sin A = \text{opp} / \text{hyp}$$

$$\sin A = \text{opp} / c$$

$$= c * \sin A$$

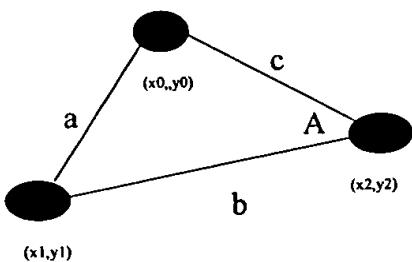
= wall distance

below, the distance between  $(x_0, y_0)$  and  $(x_2, y_2)$  is simply

$$c = ((x_2 - x_0)^2 + (y_2 - y_0)^2)^{1/2}$$

This can be used in the figure above to calculate the distance to the boundary. When this distance is less than a defined value, an audible alarm sounds. When it is less than a second and smaller value, the correction signal or shock is implemented

Basic Geometric  
Formula



Law of Cosine:

$$a^2 = b^2 + c^2 - (2bc * \cos A)$$

$$A = \text{INV COS}((b^2 + c^2 - a^2) / 2bc)$$

When calculating the angles for the queue, the law of cosines is used to calculate the angle  $A$  shown above. When this angle is greater than 151 degrees, the point is stored as a critical point for boundary purposes. Simply connecting the critical points then forms the boundary.

Interpolation can also be used to smooth a boundary.

There is no need to retrain the device after a power-off if you are going to be using the same boundary as last time the device was on. It stores those boundary coordinates between power ups. However, if you do need to retrain the module, you do this by holding down both the black and red reset buttons at the same time for just a second while the module is powered on. Once you release these buttons and begin walking around the new boundary, a new Training Phase will begin.